BRIEFER ARTICLES

PHYSIOLOGICAL NOTES. II.

(WITH THREE FIGURES)

3. An artificial endodermis cell.

Since the osmotic pressure depends upon the impermeability of the "semi-permeable" membrane to the solute, it is possible for the osmotically active matter in a cell to exert a different pressure in different directions if the protoplasm is permeable to it in different degree in different parts; and by exerting different pressures it should,

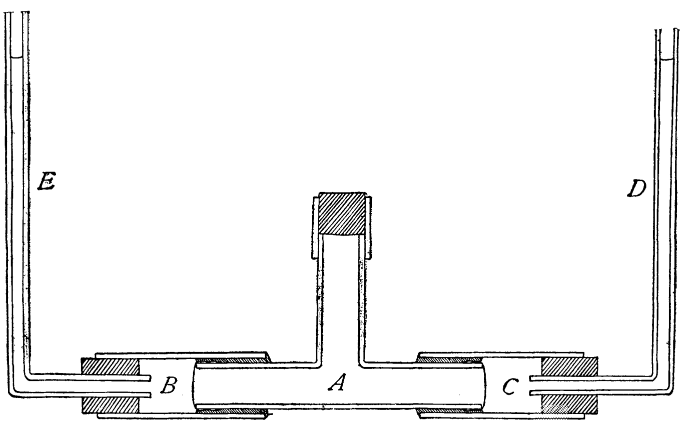

FIG. 1.

when in a state of complete turgescence, take up water where the semi-permeability is most perfect, and pass it off where the pressure is least. This is generally accepted theory, though its clearness may depend somewhat on the reason given for the entrance of the water, but its soundness has not hitherto, so far as I know, been demonstrated experimentally. This may be done as follows: over two ends of a T tube *A*, tie parchment paper; soak one of these ends thoroughly in a solution of $K_4Fe(CN)_6$; seal both ends into glass tubes, *B*, *C*, with communicating tubes, *D*, *E*, bent at right angles, fill the tubes *C*

and *D* with $K_4Fe(CN)_6$; fill *B* and *E* with distilled water, taking care that the liquids stand at the same height in *D* and *E;* fill *A* with $CuSO_4$, and close it. The membrane containing $K_4Fe(CN)_6$ is promptly filled with a precipitate of $Cu_2Fe(CN)_6$ which is practically impervious to $CuSO_4$, and any leak in this precipitation membrane will be immediately mended. The other membrane, of parchment paper alone, is relatively easily passed. The pressure against it is accordingly less. I have worked the experiment using 6 per cent. $CuSO_4$ and 3 per cent. $K_4Fe(CN)_6$. After 2 hours 15 minutes, the $K_4Fe(CN)_6$ column had fallen 1^{mm}, and the column of water had risen the same distance. Wishing to stop while the water was as pure as possible. I poured it out then, and was unable to detect any copper in it with $K_4Fe(CN)_6$; it may have been there in extreme dilution, or it may have passed into but not yet through the membrane. What had been done then was taking water out of a solution of appreciable osmotic strength, and forcing it over into practically pure water. The energy to perform this work is furnished by the loss of $CuSO_4$ from the T tube, as is easily seen if the experiment is continued longer. The concentration of the solution that is forced through the parchment membrane must obviously be at first slightly in excess of that of the $K_4Fe(CN)_6$ that the water is drawn from.

The experiment is interesting in botany, because root pressure must be caused by exactly this same process. Under certain very unlikely conditions, differences in temperature, without any loss of dissolved matter, might cause guttation, but they could not cause root pressure, because all parts of the root must be at too nearly the same temperature. That any sort of "pulsations," without variations in the resistance to the escape of the solute, could cause root pressure, will appear impossible until some adequate source of energy is shown, and if the solute escapes it is unnecessary to imagine rhythmic or any other variations. As Pfeffer suggests, pure water might be forced from a cell by local internal differences in concentration, but it would require energy whose source is unsuggested, to set up and maintain these differences.

In order that root pressure may be caused in the way that the experiment with this artificial cell illustrates, the protoplasm must be permeable to the osmotically active matter of the cell sap in different measure in different parts of itself—which is not much to expect of protoplasm, which shows a finer development of the power of internal

local differentation, for instance, in the asymmetrical growth of the wall. This power of the protoplasm might be exercised only by certain tissues or cells, as the "passage cells" of the endodermis, but probably it is by no means so restricted.

Further, the solution given out under pressure must be more concentrated than the water that enters to take its place. This does not mean, though, that if, for instance filtration is from the endodermis, the sap in the xylem must be more concentrated than the cell-sap in the cortex. For all the living cells from the root hair to the wood may cooperate as a unit, so that if the solution in the xylem is just enough stronger than the water *in the ground* to overcome the slight resistance to its passage offered by the intermediate tissues, all the physical requirements are satisfied. It is likewise absolutely unnecessary that the deeper cortical cells have more concentrated sap than the root hairs, in order to withdraw water from them; although it is usually the case that the turgor increases from the epidermis inward. When an epidermal cell has taken in all the water it can hold, the underlying cell has only to contain cell sap osmotically stronger than the ground water in order that a stream may pass through into it.

The energy which the cells exerting root pressure lose in the filtration of a part of their osmotically active matter is not (except, in part or in whole, in guttation and bleeding) a real loss to the plant. It is returned when the water and solute are separated by evaporation. So that when root-pressure raises the transpiration stream, just as when any other method—capillarity, suction, imbibition, etc.—is used, the ultimate source of energy is those rays from the sun that evaporate the water. In extreme cases root pressure amounts to an atmosphere or so. The solute necessary to explain this will have no discernible effect upon the amount of transpiration, being too insignificant beside the energy always used in evaporation, which is sufficient at ordinary temperatures to lift the mass of water evaporated, without any change in its condition, about 140 miles.—

4. The self-registration of photosynthesis.

The employment of the graphic method has proved an invaluable aid in many fields of physiological research, and has at the same time been of even more general, if of less intense, utility as a feature of class demonstration. The very simple device described here, by which the method is extended to the new field of photosynthesis,

appeals at first sight to its availability for popular demonstration. Even for purposes of investigation it is free from most of the objections to the bubble-counting method, and subject only to such as necessarily attend work on water plants.

Submerged plants of some kind are fastened where the oxygen they set free as gas is collected under an areometer. They may be fastened

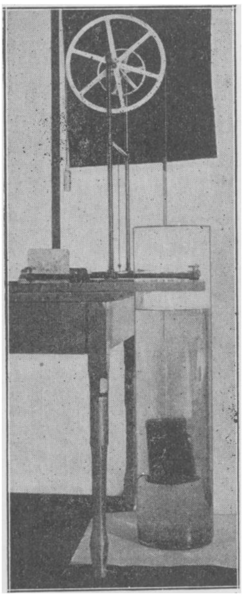

FIG. 2.[1]

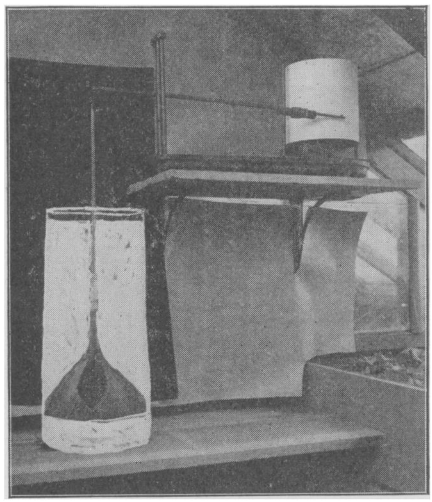

FIG. 3.

into a funnel, whose upper end is sealed into a tube of uniform external diameter, closed at the top (*fig.* 2). Or they may merely be tied into a beaker, or any other vessel, which is inverted and hung by a uniform rod. Because it is allowed to contain air, or preferably as it is held up by a counterpoise, this funnel or other vessel containing the plants stands with the uniform tube partly out of the water. As the plant assimilates, the oxygen set free displaces water, making lighter the vessel with its contents, which accordingly rises, lifting above the water a volume of the tube or rod equal to that of the oxygen evolved in the water below. It is indifferent whether the bubbles rise and

[1] Used by courtesy of the West Virginia Experiment Station.

collect in the tube or against the top of the beaker, as the larger ones do, or remain clinging to the leaves; or if only they displace water, they may stay within the tissues of the plant, and still make their record.

Of course having a rod whose upward movement shows the rapidity of the evolution of oxygen, it can very easily be made to leave its record; most accurately perhaps by means of the wheel described as the chief part of a "a new self-registering transpiration machine,"[2] but more conveniently sometimes, being less disturbed by drafts, by means of a lever auxanometer. One illustration shows it set up with a Corbett auxanometer (*fig. 2*); the other, with the wheel (*fig. 3*).

From a considerable bulk of green plant substance the evolution of oxygen is so rapid that it is necessary to use a rather large rod or get an inconveniently rapid drop of the tracer. With the auxanometer it is better to have the arms of the lever equally long. And with the wheel the tracer may be attached directly to the counterpoise, thus using only one wheel. I have tried the apparatus with Elodea and with Callitriche. The short record given here as an illustration of its work was obtained with Callitriche, May 10, beginning at 11:20 A. M., after a freezing night. The experiment was performed on the the roof, so that there were no shadows except from occasional clouds. The distance descended by the tracer and the indicated evolution of oxygen are both given. A change in weight of 1 ^{gm}, by the evolution of 1 ^{cc} of oxygen, caused the tracer to fall 17.7 ^{mm}. The registration was on a cylinder revolving in 20 minutes, but for the sake of brevity the record is condensed into one hour intervals. The temperature at 11 A. M. was 19°C.; at 1 P. M., 23°; and at 7 P. M., 21°.

	11:20–12	12–1	1–2	2-3	3-4	4–5	5–6	6–7	6:40–7
mm.	6.8	14.8	28.7	32.2	37.8	31.8	21.0	11.2	1.7
cc.O.	0.37	0.84	1.62	1.82	2.14	1.80	1.19	0.63	0.096

With the same plants on another day it was found that at 31° the evolution of oxygen was above 3 ^{cc} per hr., while at 36.4° it was only about 1 ^{cc} in the same interval. The explanation must be sought largely in the decrease in available CO_2 at the higher temperature.—EDWIN B. COPELAND, *University of West Virginia, Morgantown.*

[2] BOT. GAZ. **26**:343. 1898.